Theses and Dissertations   1. Thesis and Dissertation Collection, all items

2007-09

Assessing server fault tolerance and disaster recovery implementation in thin client architectures

Slaydon, Samuel L.

Monterey, California. Naval Postgraduate School

http://hdl.handle.net/10945/3209

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

ASSESSING SERVER FAULT TOLERANCE AND DISASTER RECOVERY IMPLEMENTATION IN THIN CLIENT ARCHITECTURES

by

Samuel L. Slaydon

September 2007

Thesis Advisor: Douglas Brinkley
Second Reader: Karl Pfeiffer

Approved for public release; distribution is unlimited

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE		*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.		
1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** September 2007	**3. REPORT TYPE AND DATES COVERED** Master's Thesis
4. TITLE AND SUBTITLE Assessing Server Fault Tolerance and Disaster Recovery Implementation in Thin Client Architectures		**5. FUNDING NUMBERS**
6. AUTHOR(S) Samuel L. Slaydon		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000		**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A		**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.		
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited		**12b. DISTRIBUTION CODE**
13. ABSTRACT (maximum 200 words) This thesis will focus on assessing server fault tolerance and disaster recovery procedures for thin-clients being implemented in smart classrooms and computer laboratories aboard the Naval Postgraduate School campus. The successful discovery of fault tolerance limits and a disaster recovery plan not only benefits the Naval Postgraduate School (NPS), but also provides the same for other commands that have implemented or plan to employ thin clients as part of their Information Technology (IT) infrastructure. Since the backbone of thin client/server-based computing (TCSBC) is the reliance on the server as the hub of processing power and data storage, it is imperative that some plan to restore the server be effected to save from the loss of valuable data. In the case of NPS, the absence of the main server not only contributes to data loss, but deprives students of hours of invaluable classroom instruction. The fault tolerance issues and disaster recovery solutions addressed in this thesis may not be suitable in all thin client architectures, but perhaps the knowledge gained through this research can aid some commands in avoiding a catastrophic server failure.		
14. SUBJECT TERMS Thin Client, Thin Client/Server-Based Computing, Total Cost of Ownership, Windows Based Terminals, Wyse, Wyse Device Management Software		**15. NUMBER OF PAGES** 63
		16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

THIS PAGE INTENTIONALLY LEFT BLANK

ASSESSING SERVER FAULT TOLERANCE AND DISASTER RECOVERY IMPLEMENTATION IN THIN CLIENT ARCHITECTURES

Samuel L. Slaydon
Major, United States Marine Corps
B.A., McNeese State University, 1996

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN INFORMATION TECHNOLOGY MANAGEMENT

from the

**NAVAL POSTGRADUATE SCHOOL
September 2007**

Author: Samuel L. Slaydon

Approved by: Dr. Douglas Brinkley
                Thesis Advisor

                LtCol Karl Pfeiffer, USAF
                Second Reader

                Dr. Dan C. Boger
                Chairman
                Department of Information Sciences

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

This thesis will focus on assessing server fault tolerance and disaster recovery procedures for thin-clients being implemented in smart classrooms and computer laboratories aboard the Naval Postgraduate School campus. The successful discovery of fault tolerance limits and a disaster recovery plan not only benefits the Naval Postgraduate School (NPS), but also provides the same for other commands that have implemented or plan to employ thin clients as part of their Information Technology (IT) infrastructure.

Since the backbone of thin client/server-based computing (TCSBC) is the reliance on the server as the hub of processing power and data storage, it is imperative that some plan to restore the server be effected to save from the loss of valuable data. In the case of NPS, the absence of the main server not only contributes to data loss, but deprives students of hours of invaluable classroom instruction. The fault tolerance issues and disaster recovery solutions addressed in this thesis may not be suitable in all thin client architectures, but perhaps the knowledge gained through this research can aid some commands in avoiding a catastrophic server failure.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGMENTS

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

A. OVERVIEW

In the past, computer users sat at a "dumb terminal" and logged into a mainframe for access to shared system resources. Over time, especially in the business world, they began to desire more from their systems than what dumb terminal technology offered. As Personal Computers (PCs) became more affordable, they introduced a welcome alternative to client/server architecture with the advantage of considerably more computing power than the dumb terminal. However, everyday users did not possess the skills necessary to implement software upgrades, introduce new applications or perform routine maintenance on their machines. Soon, the costs associated with maintaining a network that utilized PCs became overwhelming.[1]

Current thin client technologies offer the same form of access and support to users with more robust application server support at considerably less cost. Current desktop PC processing power far exceeds the vast majority of users' needs and the costs associated with hardware procurement and system maintenance can be greatly reduced by implementing thin client architectures into workspaces that offer a variety of applications to the common user.

Thin client architectures differ significantly from PC network configurations currently used throughout many

---

[1] Thin Client Movement. Accessed 6 April 2007, available at URL: http://www.tomax.com/Library/sourcefiles/whitepapers/ThinClientMovement.pdf.

business enterprises. PC networks can maximize communication speed through numerous configuration topologies, such as ring, star, bus, etc., but they rely mainly on the processing power and capabilities inherent in the Central Processing Units (CPUs) of each member PC. While PCs, which are sometimes called, "Fat Clients," rely little on the server for information retrieval and sharing, thin clients depend solely on the server for the majority of their information processing requirements.[2]

Thin clients networks have their limitations and there are issues to be considered regarding their servers as a single point of failure, associated recovery procedures and overall system maintenance. Ideally, we should be able to allow users to access shared resources via thin clients, utilizing a centralized processing source. This thesis will address the fact that the thin client server are susceptible to a hard drive failure or natural disaster and offer possible solutions to ensure fault tolerance and disaster recovery procedures.

While thin clients maintain a less complex network, they still require a particular version of software through which maintenance on the network can be administered. This thesis will also examine implementation of the WYSE Device Manager® software for the WYSE S90 thin client.

B. BENEFITS OF STUDY – WHY THIN CLIENTS?

The importance of successful communication has been the backbone of military operations since wars began. Today, it

---

[2] What is Thin Client? Accessed 6 August 2007, available at URL: http://www.pulsewan.com/data101/thin_client_basics.htm.

is not only important that communications be reliable, but they must also operate in sync with improvements in technology that continue to usher in a virtually "seamless" means of exchanging information. United States' military might owes much of its success to realizing the strategic advantages brought about by technological enhancements. Command Posts, communication stations and outlying units across the battlefields of Iraq and Afghanistan rely heavily on a secure and reliable communications backbone. These theaters of war are laboratories for the evaluation of more efficient communication devices. Thin clients offer a lighter, cheaper and more secure way of tying together each unit's communication requirements on the battlefield.

Units arriving in each of these combat zones must hit the ground running operationally. The intricacies of deploying men and women to combat zones with all of their necessary supporting equipment will always exist. The communications section that belongs to a fighting unit carries with it the tools necessary to aid in the successful completion of their unit's mission and the unit bears the responsibility, logistically and financially, for getting this equipment to the deployed area in sufficient time. Thin clients are lighter than desktop PCs, cheaper than laptops and can be administered through a single server, which lessens deployment liabilities for any unit.

C.   RESEARCH QUESTIONS

   1.   Thin Client Network Fault Tolerance

   a.   What options are available for thin client network management software?

   b.   Will the thin clients run some of the latest network administration software?

   c.   What RAID (Redundant Array of Inexpensive Disks) level should be employed in a thin client environment for server fault tolerance?

   2.   Thin Client Disaster Recovery Plan

   a.   What actions should be taken in case of a server hard drive failure in the thin client environment?

   b.   Can hard drives simply be moved or switched when one fails?

   c.   In the event of a catastrophic server failure other than hard drives, could the RAID hard drive system be moved to a backup platform?

II. LITERATURE REVIEW

A.   THIN CLIENT/SERVER-BASED COMPUTING (TCSBC)

For the purpose of this thesis, thin clients will be identified as "diskless" desktop devices that must rely on a centrally located server for computing capacity.[3]   Thin clients contain no hard drive, floppy drive or CD-ROM.

Server-based computing refers to the accessing and running of user applications from a centrally located server. The WYSE S90, used for experiments in this thesis, includes some user applications available with its Windows XP embedded (XPe) software, such as Microsoft Internet Explorer 6.0 and Windows Media Player. However, most applications are accessed and run via the centrally located server named Terminal Server 1 or "TSVR01".

B.   WYSE S90 OVERVIEW

The WYSE S90 is known as a Windows Based Terminal (WBT), as shown in Figure 1. It uses Remote Desktop Protocol (RDP) to connect to the server and display Windows applications on the user's screen.

---

[3] Thin Clients: A Cost Effective Way to Improve Security. Accessed 4 April 2007, available at URL: http://www.wyse.com/resources/whitepapers/PDF/IDC_Security.pdf.

Figure 1.   Wyse S90 Thin Client

The S90 also has two 2.0 USB ports and can be mounted on the back of a monitor, under a desk or on a wall. The WYSE S90 is the first thin client computer to be utilized for normal full-time classroom instruction aboard Naval Postgraduate School (NPS). The S90 units utilized aboard NPS are mounted on the rear of the monitors at each student workstation in Ingersoll Hall, Room 271 as shown in Figure 2. The WYSE S90's specifications will be more closely examined in Chapter III.

Figure 2.   Wyse S90 Student Workstation

Figure 3.   Wyse S90 Smart Classroom Configuration

C.   THIN CLIENT BENEFITS

1.   Hardware

Desktop PCs require routine software revisions and have a useful life of only two to three years. As a PC reaches the end of its useful life in one venue, it is often relocated, which requires yet another software upgrade.[4] Thin clients do not require software revisions at each work station since all upgrades are administered on the server. In the event that the thin client operating system may require a software upgrade, this can be administered through Wyse Device Manager Software, which will be discussed later in this thesis.

2.   Total Cost of Ownership Savings

Total Cost of Ownership (TCO) is a term established by the Gartner Group "as a comprehensive set of methodologies,

---

[4] Thin Client Benefits. Accessed 6 April 2007, available at URL: http://www.thinclient.net/pdf/Thin_Client_Benefits_Paper.pdf.

models and tools to help organizations better measure and manage their IT investments."[5] There are many costs to be considered when maintaining a computing environment. The cost associated with purchasing new systems represents only a small fraction of their Total Cost of Ownership (TCO). Systems require a considerable investment over time for services including acquisition, maintenance, upgrades, support and administration.

Since thin client architectures more easily facilitate upgrades, maintenance and new software applications via a central server, they offer quicker application deployments overall. This configuration allows for fewer man-hours spent on maintenance at every client, compared to PC configurations. Consequently, they also offer fewer expenses in client support and training. [6] Thin client architectures can also prolong life cycles of IT legacy investments since their minimal functionality requirements mean that thin client hardware seldom becomes obsolete. According to studies conducted by the Gartner Group, thin client configurations can better influence IT resources to achieve savings of 35 percent over traditional computing environments.[7]

---

[5] Why Total Cost of Ownership (TCO) Matters. Accessed 6 April 2007, available at URL:
https://k12tco.gartner.com/home/homepagepromo/files/TCO_Overview.pdf.

[6] Thin Client Movement. Accessed 6 April 2007, available at URL:
http://www.tomax.com/Library/sourcefiles/whitepapers/ThinClientMovement.pdf.

[7] Ibid.

3. Centralized Management

The ability to manage a computer network from a central hub will require fewer personnel in any IT department. According to a recent case study across various institutions that have converted the majority of their computer networks to thin client architectures, "Centralized management and reduced complexity can improve software administration, information security and business continuity, while boosting the productivity of IT staff. Compared with PC environments, thin client computing has enabled fewer IT staff to operate higher numbers of desktops."[8] This reduced network management burden will bolster the Department of Defense's focus on downsizing, while furthering the concept that even larger systems can be successfully managed by fewer personnel.

a. *More Efficient Management*

In traditional computing environments, software updates must be done on each individual PC, which is a time-consuming ordeal, especially when a new software version must be implemented t an entire network. In a thin client environment, all software updates are completed on the server. Should difficulties with the software of a particular thin client arise; the situation can be rectified remotely from the server, without having to send IT personnel to that station.

---

[8] Thin Clients: Helping Corporations Do More with Less. Accessed 13 August 2007, available at URL: http://www.wyse.com/resources/whitepapers/PDF/WyseZiff.pdf.

Most systems on a network allow for "shadowing" or some sort of remote-take-over ability to analyze a problem while speaking to a user. If the user and technician are on a separate LAN, the shadowing process can be extremely sluggish due to performance drop-off.[9] Since thin clients operate on the same LAN, connected to a single server, there is little performance drop-off during shadowing.

b.   Secure Administrator Control

Two inherent problems that network administrators face are the unauthorized modification of computer settings and loading/use of prohibited software. Network management of thin clients is only done via the server through permission of the network administrator. This keeps the potential for illegal tampering with the network to a minimum. Since thin clients have no internal memory on which user information can be stored, prohibited programs cannot be loaded onto the workstations.

c.   Security

Safeguarding information is of significant importance in most military environments. Even in unclassified work settings, information that appears innocent, but passed from a serviceman or woman to the wrong individual, could be detrimental to the command. In fat-client computing environments, information that is stored on the user's computer is more susceptible to distribution. Since all work is saved to the server and thin clients contain no local storage devices, the user cannot save

---

[9] Thin Client Benefits. Accessed 6 April 2007, available at URL: http://www.thinclient.net/pdf/Thin_Client_Benefits_Paper.pdf.

information at his or her desktop, making it more difficult to remove the data from the network. In some thin client environments, the option to save data must be allowed, like the smart classrooms aboard NPS, which facilitate the storage of information to thumb drives.

Encrypting shared data on the server can also add an extra layer of protection. Since all data is accessed via the server, work done from home can be accomplished through a remote connection to the server, so data does not have to be taken off-site.[10]

One of the ways thin clients support a more secure network is through centralization. Since security procedures are governed centrally, in thin client networks, their benefits are better realized in two key areas.

One of these areas is *security updates*. Installing the latest anti-virus and bug-fixing software is very difficult to manage in fat-client environments because it is virtually impossible to examine the information on each hard-drive, especially across larger networks. In some of these networks, ordinary desktops succumb to viruses for which preventions already exist. "Many security problems occur when machines are attacked by viruses or other elements for which there are already well-known defenses."[11] This problem can be exacerbated by organizations that expect users to download and install security upgrades by

---

[10] Thin Client Benefits. Accessed 6 April 2007, available at URL: http://www.thinclient.net/pdf/Thin_Client_Benefits_Paper.pdf.

[11] Thin Clients: A Cost Effective Way to Improve Security. Accessed 4 April 2007, available at URL: http://www.wyse.com/resources/whitepapers/PDF/IDC_Security.pdf.

themselves. As a result, some machines are not as protected as others and the resulting security scheme is a mismatched array of protected and unprotected machines.

Another security advantage through centralization is *monitoring and automation*. It is more advantageous for network security managers to have a full view of their computing environment, "with an eye on spotting and handling virus infections, security issues and other problems the moment they happen."[12] This is more easily accomplished through automation. Thin client environments allow the implementation of security procedures and software across all workstations and afford an IT manager a more transparent view of the network.

D.   CHAPTER SUMMARY

This chapter provided a basic overview of thin clients and their role in server-based computing. It also briefly mentioned the WYSE S90, which is the thin client computer primarily utilized aboard NPS in a classroom setting. The military has wisely capitalized on innovations in information technology and, therefore, could realize some definite advantages in deploying thin clients in an office or field environment. As such, some of the main advantages of thin client exploitation were examined in this chapter as well.

---

[12] Thin Clients: A Cost Effective Way to Improve Security. Accessed 4 April 2007, available at URL: http://www.wyse.com/resources/whitepapers/PDF/IDC_Security.pdf.

III. THIN CLIENT TECHNOLOGY ABOARD NPS

A.   OVERVIEW

This chapter will discuss the technological features and advantages of the thin client technology and supporting hardware used aboard NPS. It will also introduce some of the difficulties experienced during the testing and implementation of thin client remote management software.

B.   THIN CLIENT SERVER SPECIFICATIONS

There were two application servers used during the testing and evaluation for this thesis; Terminal Server 1 and Terminal Server 2. Although the basic components were made by Supermicro® Computers Incorporated, both of these servers were assembled in-house and not purchased pre-built by an outside manufacturer. In-house construction carries with it many benefits including minimizing cost, ensuring the server contains sufficient memory storage for classroom and lab applications, and making certain the server contains enough processing power to accommodate a class of 36 students. In December 2006, the first thin client classroom was constructed in Ingersoll Hall, Room 271, aboard NPS. There are a total of 36 workstations in this classroom, each containing the WYSE S90 thin client computer, a 15-inch flat-panel monitor, a mouse and a keyboard.

Terminal Server 1, nicknamed "TSVR01" is the server used to provide the processing power and applications for the thin clients in Ingersoll 271.   Terminal Server 2,

nicknamed "TSVR02" was used as the testing server to avoid any risk to TSVR01 during research experiments.

Tables 1 and 2 below show both servers' specifications:

Name	Terminal Server 1
Manufacturer	In-house design
Processor	2 x 2.6 GHz AMD Optiron 185 Dual Core
Memory	12 GB Kingston PC 3200 Registered and ECC
Storage Capacity	12 GB of RAM with 3 x 150 GB Hard Drives
Operating System	Windows Server 2003 Enterprise Edition
Drives	2 CD Drives + 3 Hard Drives
Cost	Approximately $3865.00

Table 1. Terminal Server 1 Specifications

Name	Terminal Server 1
Manufacturer	In-house design
Processor	2 x 2.6 GHz AMD Optiron 185 Dual Core
Memory	12 GB Kingston PC 3200 Registered and ECC
Storage Capacity	12 GB of RAM with 3 x 150 GB Hard Drives
Operating System	Windows Server 2003 Enterprise Edition
Drives	2 CD Drives + 3 Hard Drives
Cost	Approximately $3865.00

Table 2. Terminal Server 2 Specifications

C.   WYSE S90 IN DETAIL

There were other thin client technologies examined by the Graduate School of Business and Public Policy aboard NPS including Sun Microsystems and PC Expanion, but the one chosen for implementation on campus was from the WYSE Corporation. WYSE asserts itself as the world leader in thin client technology as they continue to work toward offering customers an affordable, extremely capable machine. Not all Wyse thin clients use the Windows XP embedded operating system. As users' needs increase, so must the technological capabilities of various operating systems. Wyse's latest thin clients are being shipped with Microsoft's Windows CE 6.0 operating system, which "enables Wyse thin computers to support the latest Windows Embedded CE-based applications while making it easier to integrate and manage peripherals such as wireless adapters, smart card readers and security solutions."[13] WYSE headquarters are in San Jose, California, but their influence on thin client technology reaches worldwide.   According to the corporation's website, "Wyse has been #1 in thin-client market share for the last seven years"[14] Wyse has also been honored as being Microsoft's "Embedded Partner of the Year" for three years and some of their clients include Gold's Gym, FedEx, Best Buy (Canada), and Quaker Foods.[15] As their list of corporate clients continues to grow, it is no wonder why Wyse has become a trusted authority on thin client technology.

---

[13] *Wyse Technology Ships Thin Clients Based on Microsoft's New Windows Embedded CE 6.0.* <u>Wireless News</u>. 21 May 2007.

[14] Wyse Technology – About WYSE.

[15] Ibid.

Before the Wyse S90, the device chosen for testing was the Wyse V90. At the time the V90 was tested, serious thin client implementation aboard NPS was in its beginning stages.   After the V90 was tested, alongside other applicable thin computers, and their capabilities were further understood, it was decided that NPS could benefit from the use of this less-expensive computing device in its smart classrooms.   The Wyse thin clients were selected because they contained more internal memory and a more robust operating system; Windows XP Embedded (XPe).   Each Wyse S90 cost approximately $550.00.   The total cost for each student workstation, including monitor, keyboard and mouse, was approximately $835.00.

1.   **Product Specifications**

Table 3 lists of software and hardware features for the Wyse Winterm S90 thin client device.

2.   **Wyse S90 System Benefits**

a.   *Immediate Setup*

The Wyse S90 is ready for connection and operation immediately upon removal from its wrapping. Installation of software is not a requirement before using the S90, which makes its setup and operation that much easier. Once it has been turned on, a connection with the network established, and user accounts created, it is ready for Remote Desktop Protocol use.

SOFTWARE	**Firmware Features**	• Microsoft Windows XPe • Microsoft Internet Explorer 6.0 resident: HTML, JavaScript, XML, Active X Sun JRE, Media Player, Citrix Web Interface • RDP 5.2 resident • Citrix ICA 8.0 resident • Sun SGD 4.2 resident • Terminal Services Advanced Client (TSAC)
	Protocol Support	TCP/IP, DNS, DHCP, PXE
	Management	• Remote management, configuration, and upgrades through Wyse Device Manager • Complete image upgrade • Wake terminal remotely (Wake-on LAN) • Terminal configuration (IP information, name, etc) • Remote screen shadowing of entire desktop (Wyse Remote Shadow)
	Set-Up and Configuration	• User interface Boot from local flash
	Server OS Compatibility/Support	• Citrix Metaframe and Presentation Server • Windows NT server, 4.0 Server, Terminal Server Edition • Windows 2000 server • Windows 2003 server
HARDWARE	**Processor**	AMD Geode GX
	Memory	512MB Flash/256MB DDR RAM
	I/O/Peripheral Support	• VGA-type video output (DB-15) • Enhanced USB keyboard with PS/2 mouse port and Windows keys • One serial port • Four USB 2.0 ports
	Networking	10/100 Base-T Fast Ethernet twisted pair (RJ-45)
	Audio	• Output: 1/8-inch mini, full 16-bit stereo, 48 KHz sampling rate • Input: 1/8-inch, 8-bit mini microphone
	Power	• Worldwide auto-sensing 100-240v VAC, 50/60Hz 5.6 watts/hr average usage with one device connected, 1 mouse and 1 monitor
	Physical Characteristics (H x W x D)	• Height: 1.38 inches • Width: 6.94 inches • Depth: 4.75 inches

Table 3. Wyse Winterm S90 Specifications[16]

[16] Wyse Products and Services. Accessed 12 June 2007, available at URL: http://www.wyse.com/products/winterm/S90/index.asp.

b.   Microsoft   Windows   XP   Embedded   Operating   System (OS)

Since Microsoft programs and operating systems are so widely used across military installations, their application has become standard in the IT infrastructure of the DoD. Any system that does not operate with Windows capability would aptly be considered an outlier, which makes the Wyse S90 and its XP embedded OS that much more attractive in the Department of the Navy IT environment. Once the S90 is turned on, the XPe OS boots up quickly and allows the user to switch effortlessly between the normal Windows PC screen to the RDP window. Windows provides an environment in which the user can run a variety of support applications, device drivers and other peripherals.

c.   Cost

While the S90 costs more than other thin client systems, it offers more to the customer, and while NPS could have saved by purchasing a less expensive system, it would have had to spend extra money on upgrading some of the lower-priced thin clients to accommodate the same functions inherent on the S90.

Hewlett-Packard's thin clients, such as the HP Compaq t5725, begin at $450.00, but its specifications do not match those included on the S90.[17] Another type of thin client, classified as "ultra-thin," such as the PC Expanion, cost approximately $195.00. The "ultra-thin" moniker is

---

[17] HP: Thin Clients for Small and Medium Business. Accessed 13 August 2007, available at URL: http://h10010.www1.hp.com/wwpc/us/en/sm/WFO4a/12454-12454-321959-338927-89307.html.

appropriate because the PC Expanion has no moving parts and comes with only a limited amount of software for its setup. The PC Expanion contains no embedded operating system and has no USB drives.[18] Its low price is appropriate for lightweight, simple thin computing solution, but it has limited capability when compared to the S90.

For example, the S90's Windows XPe capability accommodates thumb drives where thin clients that utilize other operating systems do not. Some may also argue that for the price of the S90, a basic PC could have been purchased, but the lower maintenance costs and longer life expectancy of the S90 makes it less expensive overall.

d.   Lower Maintenance Requirements

Since the S90 has no moving parts such as a fan or disk drive, its maintenance burden is exceptionally low. This durability is a tremendous factor when considering systems that must be used outdoors during field operations where dust, sand and moisture can corrode the moving parts of more complex desktop systems.

e.   Portability

Since computers have become an integral part of today's military operations, getting them to and from an area of operations presents a considerable challenge to a unit. The compact size of the S90 makes it lighter and more space efficient than a normal desktop PC. At least three or

---

[18] What is PCExpanion? Accessed 13 August 2007, available at URL: http://www.doublesight.com/prod_pcexpanion.htm.

19

four S90s can fit in the same space that a conventional PC would occupy, providing a significant logistical advantage.

D.   WYSE DEVICE MANAGER (WDM) SOFTWARE

While most of the administration in the thin client environment takes place on a remote server, some maintenance will be required on the operating system itself. Since the Wyse S90s are deployed with Windows XP embedded operating system, they carry with them the risks associated with utilizing this software, which means required maintenance is inevitable. While modifying the Windows settings can be done at each individual terminal, it is more desirable to deploy such changes across the entire network of thin clients. Wyse Device Manager (WDM) Software, formerly known as Rapport, is the tool for implementing such modifications.

While Wyse my be a leader in thin client technology, it was discovered that its Device Manager software was neither user friendly nor easily implemented and required one graduate student's entire quarter under directed study to unlock its potential.

Operating system information on the S90 is protected by the Enhanced Write Filter (EWF), which must be turned off when maintenance is performed.[19] The EWF can be seen on the lower right hand side of the screen as either a green or red dot. If the dot is green the write filter is enabled and no changes can be made to the operating system. If the dot is red, the write filter has been disabled and the operating system is open to administrative changes.

---

[19] Schearer, Captain Steven A., "Remote Administration of Wyse S90 Thin Client Computers", *Naval Postgraduate School Directed Study.* 24 April 2007.

In order to disable the write filter, an administrator must log on to that particular machine and double click the green dot, which will cause the machine to reboot. Once it reboots, the red dot will show, indicating that changes can now be made to the system. The write filter is enabled again by clicking on the red dot, which reboots the system once more, saving any changes made during maintenance.

Before the WDM software was introduced, any required changes made to the thin clients in the smart classroom were conducted in this manner. The write filter was disabled at each machine, required maintenance was performed, and the EWF was once again enabled. Not only was this process time consuming, but it gave way to a margin for error. If an administrator forgot to enable the write filter, the system would be open to student tampering, which could result in significant damage to the thin client.

The workgroup version of WDM software was selected for use for experiments involving remote configuration and can be downloaded at no charge from the Wyse Corporation's website. It supports a network of up to 750 thin clients; however, upgrades can only be administered to five clients at once, which is one of the most prominent limitations of this version of WDM.[20]

There are two ways to remotely configure thin clients through WDM; either by re-imaging the entire system or selective package application. However, one of the dangers involved in applying an image across the system is that once

---

[20] Schearer, Captain Steven A., "Remote Administration of Wyse S90 Thin Client Computers", *Naval Postgraduate School Directed Study.* 24 April 2007.

the brand new image is applied, it will erase any existing operating system settings. Selective package application offers the most hassle-free method of deploying changes and software updates to the thin client network through a feature called "Package Manager" in WDM. Through Package Manager, Wyse offers certified Microsoft patches that are ready-to-deploy once downloaded from their website and can be administered without erasing any existing system configurations.[21]

E. CHAPTER SUMMARY

This chapter introduced the reader to an in-depth description of the Wyse S90 and its specifications, as well as the reasons it was selected as the thin client of choice on the NPS campus. Also examined were the specifications for the thin clients' primary server (TSVR01) and the secondary server (TSVR02), which was used during experiments for this thesis. Additionally, this chapter familiarized the reader with the software used for remote administration of Wyse thin clients as well as some of the problems discovered during its implementation.

---

[21] Schearer, Captain Steven A., "Remote Administration of Wyse S90 Thin Client Computers", *Naval Postgraduate School Directed Study.* 24 April 2007.

IV. EXPERIMENTS

A. BACKGROUND

After building our experimental server, TSVR02, it had to be configured so that its communication with the Wyse S90 could be tested. The initial software load on TSVR02 was Windows Server 2003 Standard Edition and the first network connectivity tests for TSVR02 took place in Ingersoll Hall, Room 380, which is used as a secondary computer lab by the Graduate School of Business and Public Policy (GSBPP). Once the software was loaded onto TSVR02, the next step was to determine whether or not a remote desktop connection could be established from the thin client to TSVR02. To do this, a console was created on TSVR02, named "SlaydonConsole070119", which would be used to configure user accounts on the server. Using the steps below, four experimental user accounts were created on the server.

```
     To Create Users/Groups:
     a)   Go   to   Start/Control   Panel/Administrative
Tools/Computer Management
     b) Right click "Users" in the Computer Management
menu
     c) Select "New User"
     d) User name: Student1
        Full name:  Samuel Slaydon
        Description:  NPS Student
        Password:  Password (to be changed at login...new
password will be Nps1234)
     e) By default "Student1" was added to the User group
     f) Add "Student1" to the Remote Desktop Users group
```

Once this first account was added, a log-on attempt was made from a thin client to TSVR02 using the Windows RDP client on the S90. Once log-in procedures were initiated, the user was prompted to change the password (which is correct according to the steps listed above). Once the password was changed, log-in to TSVR02 was successful. The same procedures were repeated for the other four experimental accounts and all log-ins were successful.

B. EXPERIMENT I

1. Purpose of Conducting Experiment

The thin clients aboard NPS used by faculty and students in the smart classroom are dependant upon a single server, the aforementioned TSVR01. If TSVR01 ceases to operate, due to either a hard drive failure or catastrophic event, another server must be brought on-line as quickly as possible in order to maintain scheduled class periods and exams proctored in the smart classroom. This experiment examined the possibility of a "hard drive swap" as a thin client disaster recovery procedure.

2. Preparations for the Experiment

In order to save TSVR01 from unnecessary damage, it was not used during this experiment. The aforementioned testing server TSVR02 was used as the "broken" server. An additional server that was being utilized as a backup in a GSBPP civilian contractor's offices, called "TSVR03", was used to test the swapped hard drive. The hard drive in TSVR02 contained the Windows Server 2003 operating system, along with the bogus student accounts created above.

3.   Experiment Execution

a.   The hard drive from the "damaged" server, TSVR02, was removed after it had been tested and determined that its student accounts were accessible from the thin client.

b.   All drives were removed from TSVR03 before inserting the hard drive from TSVR02.

c.   The hard drive was placed in the top hard drive slot of TSVR03.

d.   Upon the first attempt to reboot the server, there was an immediate "Boot Configuration Error" showing on the screen.

1) It was determined that the RAID array on TSVR03 had not been reconfigured for this experiment.

2) The hard drives in TSVR03 had been used under a specific RAID array and when the "new" hard drive was inserted, it was trying to read the hard drives in the order for which it had been configured. When it could not find the other drives, it provided the error.

e.   The computer was rebooted and RAID was disabled in the setup menu.

f.   After RAID was disabled, the computer was restarted and it was operational.

g.   TSVR03 demonstrated connectivity with the network.

h.   The Microsoft Management Control (MMC) "disk management" showed that the swapped hard drive was healthy.

i.   A log-on attempt from a thin client to TSVR03 was attempted.

1) Received an error message stating, "The remote session was disconnected because there are no Terminal Server license servers available to provide a license."

2) This is a Terminal Services licensing issue generated because Microsoft did not recognize the new machine on which the operating system was now operating.

4.   Results and Conclusions

The licensing error that appeared upon the attempted log-in via thin client presented a financial challenge to the GSBPP department. While Terminal Server licenses can be purchased in bundles, they cost thousands of dollars. Instead of spending this money based on the merits of a single experiment, Doctor Brinkley decided to initiate the possibility of linking TSVR01 with TSVR02 and TSVR03 in a server clustering exercise. The next experiment details cover the conclusions of that exercise.

C.   EXPERIMENT II

1. Purpose of Conducting Experiment

Due to the high cost of Terminal Server licenses, the option of server clustering presented a possible alternative. If successful, server clustering presents a viable solution to the possibility of a hard drive failure in TSVR01. In a server cluster, each of the servers are linked and the backup servers, TSVR02 and TSVR03, constantly update their hard drives, with the aid of specific hardware and software, which creates a mirror image of the information contained on TSVR01's drive. In the event of TSVR01's failure, students and faculty could simply be

instructed to log on to one of the other backup servers until TSVR01 could be repaired.

2.   Preparations for the Experiment

The hard drive that had been removed from TSVR02 for the first experiment was replaced in that machine. In order to run essentials necessary in creating a server clustering environment, the servers in question must run certain software.   For this experiment, Microsoft Server 2003 Enterprise Edition is required, and its implementation will be further discussed in this experiment.

3.   Experiment Execution

a.   A copy of MS Server 2003 Enterprise Edition is received from the Graduate School of Information Sciences (GSOIS), attainable through the Microsoft Developer Network Academic Alliance (MSDNAA) program.

b.   The hard drive from TSVR02 remained healthy following the first experiment.   In this light, it was decided that TSVR03's hard drive would be used to test the MS Server 2003 Enterprise Edition Software in beginning the Server Clustering Exercise.

c.   First, the boot order was reconfigured on TSVR03 so it would boot off of the CD-ROM.

d.   During the installation of MS Server 2003 Enterprise Edition, 100,000 megabytes were partitioned for server use, and another 50,000 were set aside for other use.

e.   Installation of the software was successful, so all of the necessary drivers were downloaded and installed as well.

f.   A Microsoft Management Console (MMC) named "SlaydonConsole070220" was created with the following add-ins: Disk Management (Local), Local Users and Groups (Local), Computer Management (Local) and Device Manager on Local Computer.

g.   Users, Groups, and "Student" accounts were created using the steps located on pages 23 and 24.

h.   A Remote Desktop Connection from a thin client to TSVR03 was attempted, but this received an error message, which were corrected utilizing the following steps:

  1)   Go to Start/Control Panel/System

  2)   On the Remote tab, enable Remote Desktop

  3)   Go to Start/Administrative Tools/Terminal Services Configuration, right click the RDP-tcp icon and click Properties.

  4)   On the Network Adapter tab, Maximum Connections was changed to one.

  5)   Select both Override User Settings check boxes and made the following changes to session limits:

    i) End a disconnected session: 15 minutes.

    ii) Active Session Limit: Never.

    iii) Idle Session Limit: 15 minutes.

    iv) When session limit is reached or connection is broken: Disconnect from session.

i.   Attempted Remote Desktop Connection from thin client to TSVR03 and was successful for all student accounts. All passwords were then changed.

j.   Instead of wiping the disk in TSVR02, loading MS Server 2003 Enterprise Edition and manually creating an image of the hard drive from TSVR03, we will try to copy the image from one hard drive to another by simply placing the hard drive from TSVR02 in one of TSVR03's hard drive slots.

k.   Upon attempting to burn the image from TSVR03 on to TSVR02's hard drive, we discovered that the copy had accidentally been done in reverse order, i.e., the information from TSVR02 was transferred onto TSVR03's hard drive.

l.   This was corrected by simply reapplying steps e and g above.

m.   The Server Clustering Exercise was terminated before completion.

4.   Results and Conclusions

The guide used for the Server Clustering Exercise was a white paper entitled, "*Microsoft Windows Server 2003; Technical Overview of Clustering in Windows Server 2003,*" published by the Microsoft Corporation in January 2003. This paper listed specifics involved in setting up and operating a server cluster. The steps listed above for this experiment were merely preparations to begin the Server Clustering exercise. Very few clustering essentials listed in the aforementioned white paper had been examined thoroughly, save the upgrade from MS Server 2003 Standard

Edition to MS Server 2003 Enterprise Edition, which is the required operating system for server clustering.

Upon closer examination of those pieces essential for server clustering, it was determined that it would be too expensive an endeavor to support only a single smart classroom of thin clients. One of the standard Microsoft essentials for maintaining a successful server cluster is that each cluster must contain hardware named on the Microsoft Hardware Compatibility List (HCL). The costs associated with ensuring that each necessary piece of hardware listed on the HCL were acquired ranged from $10,000 to $12,000. At this time it was determined that a simpler, less expensive route toward disaster recovery should be determined.

D.   EXPERIMENT III

1.   Purpose of Conducting the Experiment

After closer review of the Server Clustering option and the expenses in adopting such a configuration were realized, a less expensive option was desired. Along the lines of Experiment I, copying the information from a damaged server to a healthy one still seemed like a simpler and cheaper option. If the main server fails, a duplicate server containing the exact information, including all user accounts and information, etc., could serve as its replacement with only minimal maintenance time in between the information swap. The problem that still remained was the possible expensive licensing issue incurred in the first experiment in the attempt to swap hard drives from one machine to another. It was determined that transferring the

information from TSVR01 to an external hard drive was another option for experiment. The GSBPP department had plenty of external hard drives for use and extras can be purchased at relatively low cost.

2. Preparations for the Experiment

Since the information to be copied was on TSVR01, no changes to that server's configurations were required to begin the experiment. TSVR01 would act as the "damaged" server during the experiment. The server used as the undamaged server was TSVR02. In order to ensure the experiment ran properly, both servers were utilizing the same operating system, which was Microsoft Windows Server 2003 Enterprise Edition. The probability that TSVR01 would become damaged during this experiment was unlikely; however, to ensure none of its users lost any critical information in the event of an accident, all users were notified that the server would be off-line for the duration of the experiment. TSVR01 was also taken offline to ensure that administrators and "users" could log-in to TSVR02 once it was booted with TSVR01's information.

3. Experiment Execution

a.   The external drive used for this experiment was a Maxtor® 300GB hard drive.

b.   Utilizing a program called EZ Gig®, the information was transferred from TSVR01's active hard drive to the Maxtor® external drive with no problems.

c.   Once the information was successfully transferred, the external drive was plugged into a USB port on the back of the TSVR02 CPU.

d.   The boot order on TSVR02 was reconfigured so that it would boot from the external drive upon startup.

e.   TSVR02 booted with no problems and all of the information contained on TSVR01's main hard drive was present.

f.   To ensure all accounts on TSVR01 were still accessible, log-on attempts were made by TSVR01 administrators. These log-on attempts were successful.

g.   A log-on attempt was made from one of the thin clients in the thin clients smart classroom to the "new" TSVR01 and was also successful, with no licensing error message.

4.   Results and Conclusions

At this point it was determined that transferring the hard drive information from the main server to an external one, and then booting the backup server with this information, was the most efficient method discovered for administering a successful disaster recovery scheme in case of server failure. One of the most attractive points of this method of disaster recovery is that it is relatively inexpensive and uncomplicated. External hard drives are easy to find, compact and come in a variety of memory sizes. Undoubtedly, the information contained on the main server will grow larger as the requirements of the institution increase, so a cost-effective method of ensuring important

information is always accessible, even in the event of an emergency, is worth the effort.

Another attractive advantage of this method is that external hard drives can be subject to scheduled backups. Programs like the aforementioned EZ Gig® are commonly used to copy large amounts of information from one hard drive to another, and can be configured to perform scheduled back-ups of critical information. If backups are properly configured to take place automatically, up to date information from the healthy server will always be available in case of its failure.

E.   CHAPTER SUMMARY

This chapter focused on outlining three experiments for discovering a successful method of disaster recovery in the case of a main server failure. The chosen method was not only successful, but provided an inexpensive, straightforward solution through which more extensive organizations, with even larger servers, could utilize to bolster fault tolerance procedures.

THIS PAGE INTENTIONALLY LEFT BLANK

V. SUGGESTIONS FOR FURTHER RESEARCH

A.   SMART CLASSROOMS

The smart classroom in Ingersoll Hall, Room 271, has been operational since January 2007. Overall, there have been few problems with the smart classroom thin clients, which arose mainly because this was the first time they had been used in such a capacity aboard NPS. Early on, many of the difficulties centered on students' tampering with the thin clients' security features, such as saving data to the desktop or server or changing the administrative passwords. Other difficulties included configuring the networked classroom teaching program used in the smart classroom, called NetOp®. Since, most of these difficulties have been resolved and the support staff have gained considerable experience maintaining the systems. The prototype thin client installation has proven the technology's advantages outweigh the disadvantages and the Graduate School of Business intends to expand the use of thin clients in their classrooms.

B.   WIRELESS THIN CLIENTS

The success of the smart classroom may lead to the construction of other thin client learning venues across campus. Since NPS is a wireless integrated campus, the application of wireless thin clients is suggested as a topic for further research. Wireless technology allows thin clients to be deployed faster and easier, since considerably less wiring is required. There are many corporations that

build wireless thin clients, including Wyse, BOSaNOVA and Hewlett-Packard that support a variety of operating systems including Windows CE, Windows XP and Linux. Although the Wyse Corporation was the choice supplier of thin clients for the first smart classroom, a thorough review of a number of companies' thin client technologies may be in order if wireless thin client implementation is seriously considered.

1. Wyse V90

Wyse V-Class thin clients are equipped with an integrated wireless adapter that can be configured to connect with most wireless networks. The Wyse V90 is the most equipped of the V-Class thin clients and comes with Windows XP embedded Service Pack 2 software, similar to the S90. Below are images of the Wyse V90. A list of its specifications is listed on page 38.

Figure 4.   Wyse V90 Thin Client.

2. BOSaNOVA XTC-1300

Like the Wyse V90, the BOSaNOVA XTC-1300 is available with internal wireless capability. Their thin clients also operate on Windows XP, Windows CE and Linux platforms. The

XTC-1300 is the "top of the line" Windows XP embedded wireless thin client that BOSaNOVA offers. Below are images of the XTC-1300. A list of its specifications is listed on page 39.

Figure 5.   BOSaNOVA XTC-1300 Thin Client

3.   Hewlett-Packard Compaq t5720 Thin Client

This thin client model from HP is not delivered with integrated wireless capability, but a wireless PCI card can be purchased as an upgrade to the t5720. The t5720 is another model that comes standard with Windows XP embedded software; although HP's thin clients support Windows CE and Linux operating systems as well. Below are some images of the t5720. A list of its specifications is listed on page 40.

Figure 6.   Hewlett-Packard Compaq t5720 Thin Client

SOFTWARE	**Firmware Features**	• Microsoft Windows XPe • Microsoft Internet Explorer 6.0 resident: HTML, JavaScript, XML, Active X Sun JRE, Media Player, Citrix Web Interface • RDP 5.2 resident • Citrix ICA 8.0 resident • Sun SGD 4.2 resident • Terminal Services Advanced Client (TSAC)
	Protocol Support	TCP/IP, DNS, DHCP, PXE
	Management	• Remote management, configuration, and upgrades through Wyse Device Manager • Send messages • Complete image upgrade • Wake terminal remotely (Wake-on LAN) • Terminal configuration (IP information, name, etc) • Remote screen shadowing of entire desktop (Wyse Remote Shadow)
	Set-Up and Configuration	• User interface • Boot from local flash
	Server OS Compatibility/Support	• Citrix Metaframe and Presentation Server • Windows NT server, 4.0 Server, Terminal Server Edition • Windows 2000 server • Windows 2003 server
HARDWARE	**Processor**	Via C3
	Memory	512MB Flash/256MB DDR RAM
	I/O/Peripheral Support	• VGA-type video output (DB-15) • Enhanced USB keyboard with PS/2 mouse port and Windows keys • Two Serial Ports • Three USB 2.0 ports
	Networking	• 10/100 Base-T Fast Ethernet twisted pair (RJ-45) • Internal 802.11b/g wireless solution
	Audio	• Output: 1/8-inch mini, full 16-bit stereo, 48 KHz sampling rate • Input: 1/8-inch, 8-bit mini microphone
	Physical Characteristics (H x W x D)	• Height: 7.9 inches • Width: 1.8 inches • Depth: 7.1 inches

Table 4. Wyse V90 Specifications[22]

---

[22] Wyse Products and Services. Accessed 15 August 2007, available at URL: http://www.wyse.com/products/winterm/V90/index.asp.

SOFTWARE	Firmware Features	• Microsoft Windows XPe SP2 • Microsoft Internet Explorer 6.2 • RDP Version 6.0 • ICA Version 9 • CA's eTrust Antivirus for XPe
	Protocol Support	Not listed
	Management	• BOSaNOVA Remote Manager • Push/Pull Updates • VNC
	Set-Up and Configuration	• User interface
	Server OS Compatibility/Support	None listed
HARDWARE	Processor	Via C7 Ester 1.3 GHz
	Memory	• 512 MB – 1 GB DDR2 RAM • 512 MB – 4 GB Flash
	I/O/Peripheral Support	• 1 Parallel Port • Enhanced USB keyboard with PS/2 mouse port and Windows keys • Two Serial Ports • Four USB 2.0 ports
	Networking	• Autosensing, 10/100 Ethernet, RJ-45, WakeOnLan, PXE Boot • Internal/External 802.11b/g wireless solution
	Audio	• Internal speakcer • Mic In/Line Out
	Power	• 100-240v VAC, 50/ • Max AC Input Power: 15W
	Physical Characteristics (H x W x D)	• Height: 11.5 inches • Width: 2.0 inches • Depth: 8.2 inches

Table 5.   BOSaNOVA XTC-1300 Specifications[23]

---

[23] BOSaNOVA Products. Accessed 15 August 2007, available at URL: http://www.bosanova.net/thinclient/xpe-1300.html.

SOFTWARE	**Firmware Features**	• Microsoft Windows XPe • Microsoft Internet Explorer 6.0 • Altiris manageability agent (full version) • Citrix ICA 9.x Program Neighborhood • Microsoft RDP 5.2 • Terminal Emulation Console software	
	Protocol Support	Not listed	
	Management	• Image and BIOS manageable via Altiris Deployment Solution • FTP and DHCP settings update feature • ThinState Capture and Deploy tools included with each client • HP OpenView Client Configuration Manager support available	
	Set-Up and Configuration	Not listed	
	Server OS Compatibility/Support	• Microsoft Windows NT 4.0 Server • Windows 2000/2003 Server families • Windows 2000/2003 Server Terminal Services • Windows 2000 Advanced Server	
HARDWARE	**Processor**	AMD Geode NX 1500	
	Memory	• 256MB or 512MB or 1GB DDR SDRAM • 1GB or 512MB Flash	
	I/O/Peripheral Support	• SiS741 GX Integrated/UMA Graphics with 16MB shared graphics memory • Enhanced USB keyboard with PS/2 mouse port and Windows keys • One Serial Ports/One Parallel Port • Six USB 2.0 ports	
	Networking	• TCP/IP with DNS and DHCP support • 10/100 Base T Fast Ethernet, twisted pair (RJ-45) • Point-to-Point Protocol (PPP), Direct Connection through RS-232 • VPN Connection through MS Point-to-Point Tunneling Protocol (PPTP) • Layer 2 Tunneling Protocol (L2TP) • Simple Network Management Protocol (SNMP)	
	Audio	• 1/8-inch mini output, full 16-bit stereo, 44KHz sampling rate	
	Physical Characteristics (H x W x D)	Not listed	

Table 6. Hewlett-Packard Compaq t5720 Specifications[24]

---

[24] HP: Thin Clients for Small and Medium Business. Accessed 15 August 2007, available at URL:
http://h10010.www1.hp.com/wwpc/us/en/sm/WFO4a/12454-12454-321959-338927-89307.html.

B.   CHAPTER SUMMARY

This chapter introduced the concept of wireless thin clients for use in further implementations of the smart classroom model aboard NPS. The specifications of each of the thin clients listed in this chapter presented only a brief overview of some of their capabilities as listed on corporate specification sheets. A more thorough review, through experiments, hands-on trials, and use in a classroom setting should be conducted before their wireless capabilities can be more aptly determined.

THIS PAGE INTENTIONALLY LEFT BLANK

VI. CONCLUSION

There are plenty of arguments about the eventual end to the conflicts in Iraq and Afghanistan, but to this day there seems to be no outlook on the de-escalation of the war. With that in mind, the current budget of the War on Terror will become increasingly strained and U. S. forces, at home and abroad, will continue to be compelled to strive for the same operational tempo with a reduced amount of funding. Thus, a lighter, faster military is envisioned.

This more agile military will require an IT infrastructure that is capable of supporting its forces, whether at home or abroad. For servicemen and women stationed in the U. S. supporting those troops overseas, thin clients offer a reduced maintenance burden, less Total Cost of Ownership (TCO), and the ability to manage their system through a centralized server.

Thin clients offer many advantages to deployed units as well. Their reduced logistical burden means that a unit has to carry less IT equipment to the field. Once a unit arrives at its Area of Operation(AO), thin clients can be set up quickly and connect to an existing IT infrastructure with little difficulty since only one machine (the server) has to be connected to the backbone. Thin clients also have less moving parts, so the dust and sand inherent in many deployed locations are not as significant a threat to their components.

Although the use of thin clients is not accepted unilaterally across the DoD, the benefits of their applications cannot be ignored. As presented in this

thesis, there are many advantages to implementing thin client architectures in the DoD, especially in light of current operations in Afghanistan and Iraq. U. S. military prowess and IT infrastructures share one point of significant importance; the ability to do more with less.

LIST OF REFERENCES

3Com Corporation. 1999. "What is Thin Client?" Available at URL:http://www.pulsewan.com/data101/thin_client_basics.htm. Accessed 6 August 2007.

Barrie, David. March 2002. "Thin Client Benefits." Available at URL: http://www.thinclient.net/pdf/Thin_Client_Benefits_Paper. pdf. Accessed 6 April 2007. [19 pages.]

Gartner, Incorporated. 2003. "Why Total Cost of Ownership (TCO) Matters." Available at URL: https://k12tco.gartner.com/home/homepagepromo/files/TCO_Over view.pdf. Accessed 6 April 2007. [11 pages.]

HP Corporation. "HP: Thin Clients for Small and Medium Business." Available at URL: http://h10010.www1.hp.com/wwpc/us/en/sm/WFO4a/12454-12454-321959-338927-89307.html. Accessed 13 August 2007.

O'Connell, Bob. IDC Executive Brief. January 2004. "Thin Clients: A Cost Effective Way to Improve Security." Available at URL: http://www.wyse.com/resources/whitepapers/PDF/IDC_Security.p df. Accessed 4 April 2007. [6 pages.]

Schearer, Captain Steven A. April 2007. "Remote Administration of Wyse S90 Thin Client Computers." Naval Postgraduate School Directed Study.

Tomax Retail. "The Thin Client Movement." Available at URL:http://www.tomax.com/Library/sourcefiles/whitepapers/Thi nClientMovement.pdf. Accessed 6 April 2007.

Wyse Corporation. June 2004. "Thin Clients: Helping Corporations Do More with Less." Available at URL: http://www.wyse.com/resources/whitepapers/PDF/WyseZiff.pdf. Accessed 13 August 2007.

"Wyse Technology Ships Thin Clients Based on Microsoft's New Windows Embedded CE 6.0." Wireless News. 21 May 2007. Dudley Knox Library, Naval Postgraduate School, Monterey, California. 5 August 2007 <http://www.proquest.com.libproxy.nps.edu/>

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California

3. Dr. Douglas Brinkley
   Naval Postgraduate School
   Monterey, California

4. Lieutenant Colonel Carl Pfeiffer, USAF
   Naval Postgraduate School
   Monterey, California

5. Dr. Dan C. Boger
   Naval Postgraduate School
   Monterey, California